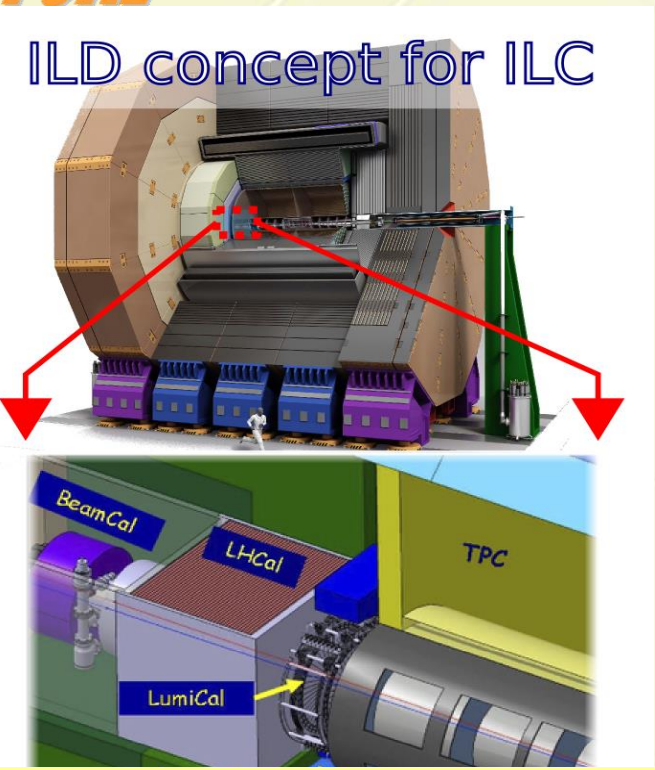
FCAL - Results from Testbeams and Future Plans

Wolfgang Lohmann, BTU and DESY

On behalf of the FCAL Collaboration

AGH University of Science and Technology Cracow, ANL Argonne, CERN Geneva, DESY Zeuthen, IFIN-HH Bukharest, INPPAN Cracow, ISS Bukharest, LAL Orsay, JINR Dubna, NCPHEP Minsk, Pontificia Universidad Catolica de Chile, SLAC Stanford, Tel Aviv University, Tohoku Univ. Sendai, Univ. of Colorado Boulder, UC California Santa Cruz, Vinca Belgrade

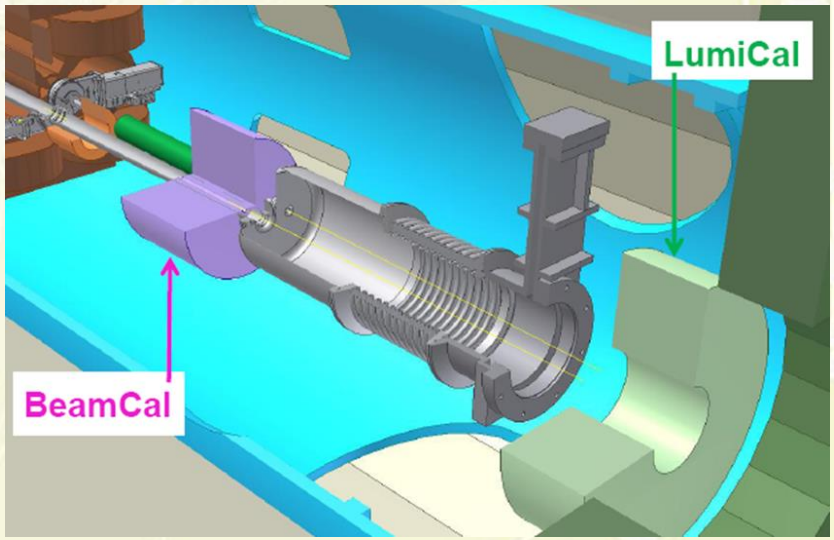
The Very Forward Region of a LC Detector



Two very compact electromagnetic Calorimeters, BeamCal and LumiCal

- Fast luminosity and beam parameter measurement, fast feedback (BeamCal)
- Precise luminosity measurement (LumCal)
- Coverage at small angle - hermeticity
- Mask for the inner detectors

CLIC Detector Design

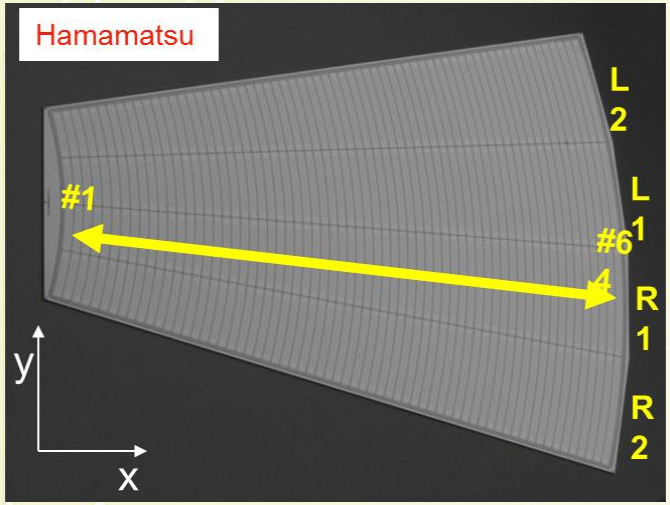


Challenges:

- High precision devices (LumiCal)
- High Occupancy
- High Radiation Tolerance (BeamCal)
- Fast Readout electronics

Sensors

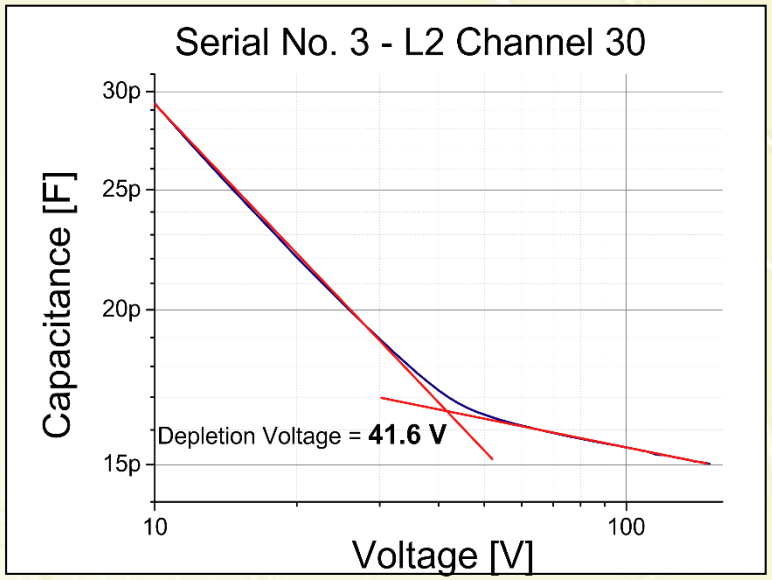
Silicon sensor prototype for LumiCal

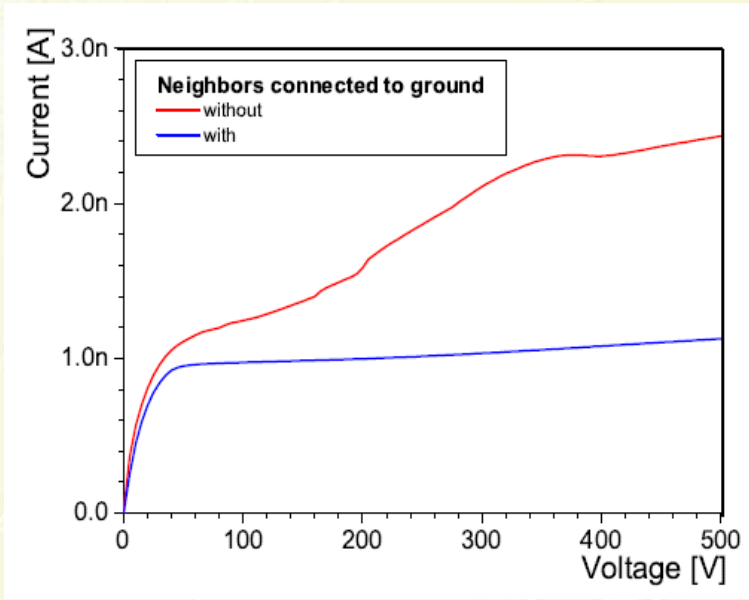


p in n, strip pitch 2.2 mm

40 pieces, joint effort (IFJ PAN Cracow, DESY, TAU)

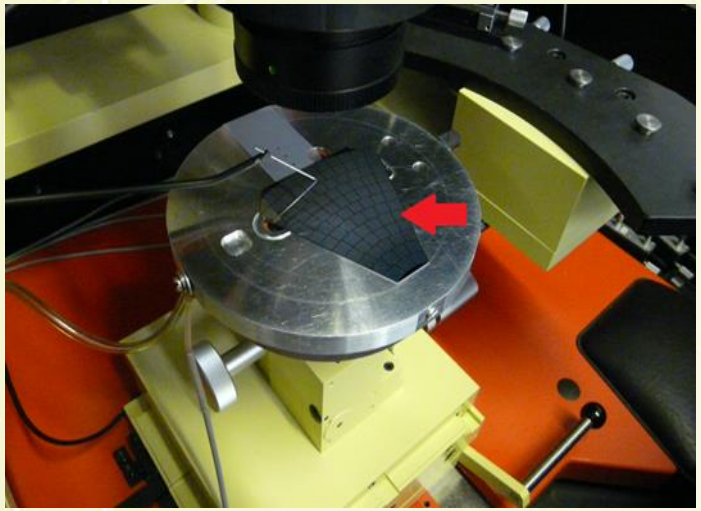
Electrical characterisation done, matches quality criteria

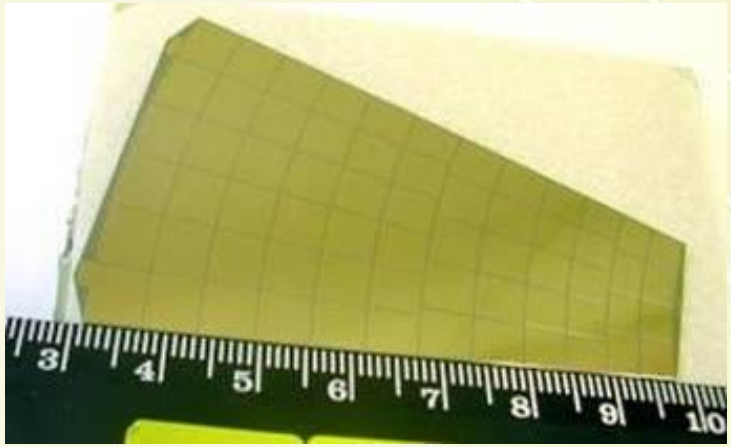


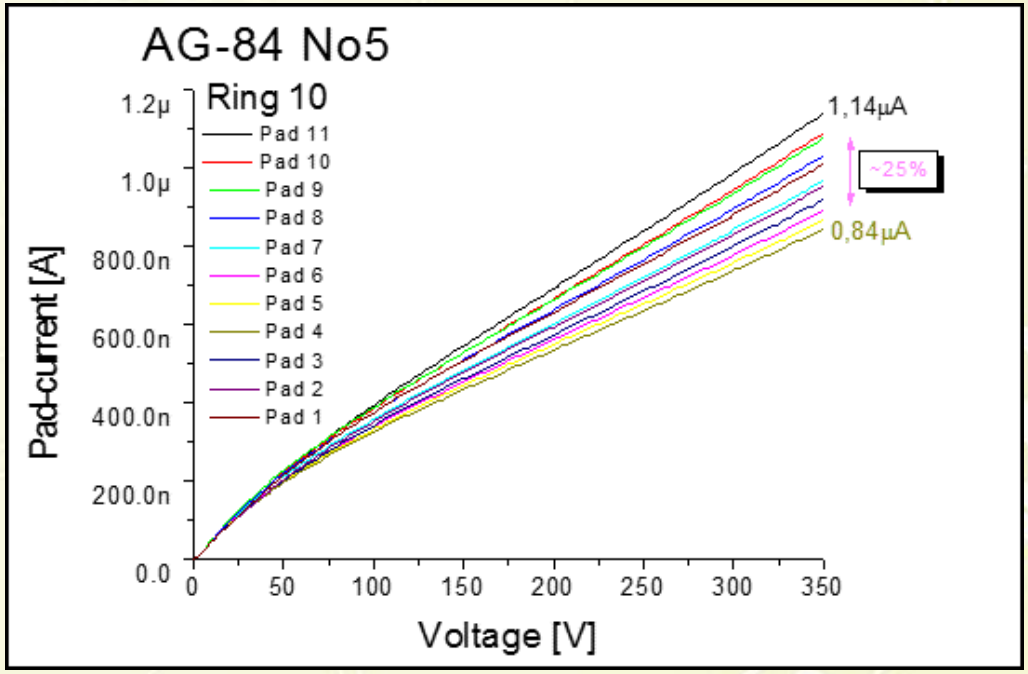


Sensors

Characterisation of a GaAs sensor on the probe-station







Compensated GaAs

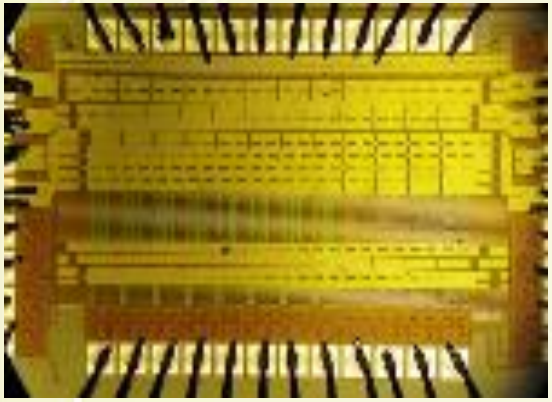
Institute in Tomsk, DESY-JINR collaboration (BMBF supported)

Characterised at JINR and DESY

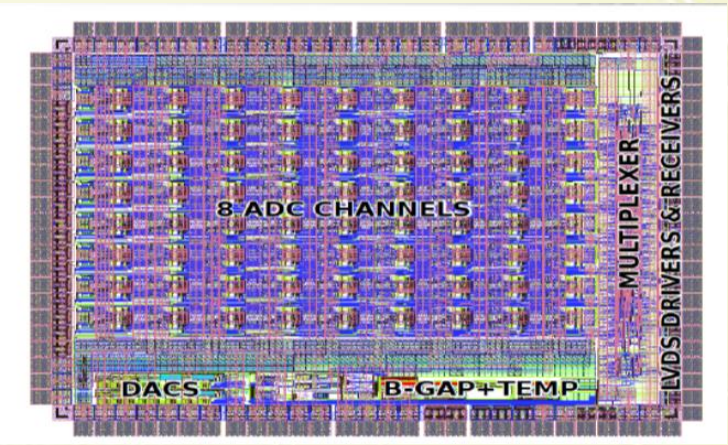
Radiation hardness studies (1.5 MGy) published JINST 7 (2012) P11022

ASICs

FE and ADC ASICs in 350 nm AMS technology (UST Cracow)

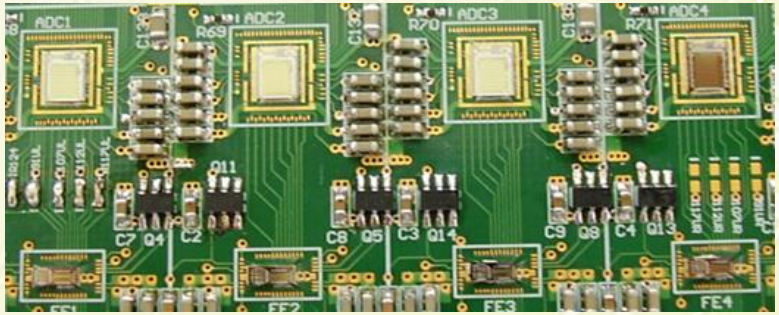


FE ASIC, 8 channels, 4 RC and 4 FET feedback

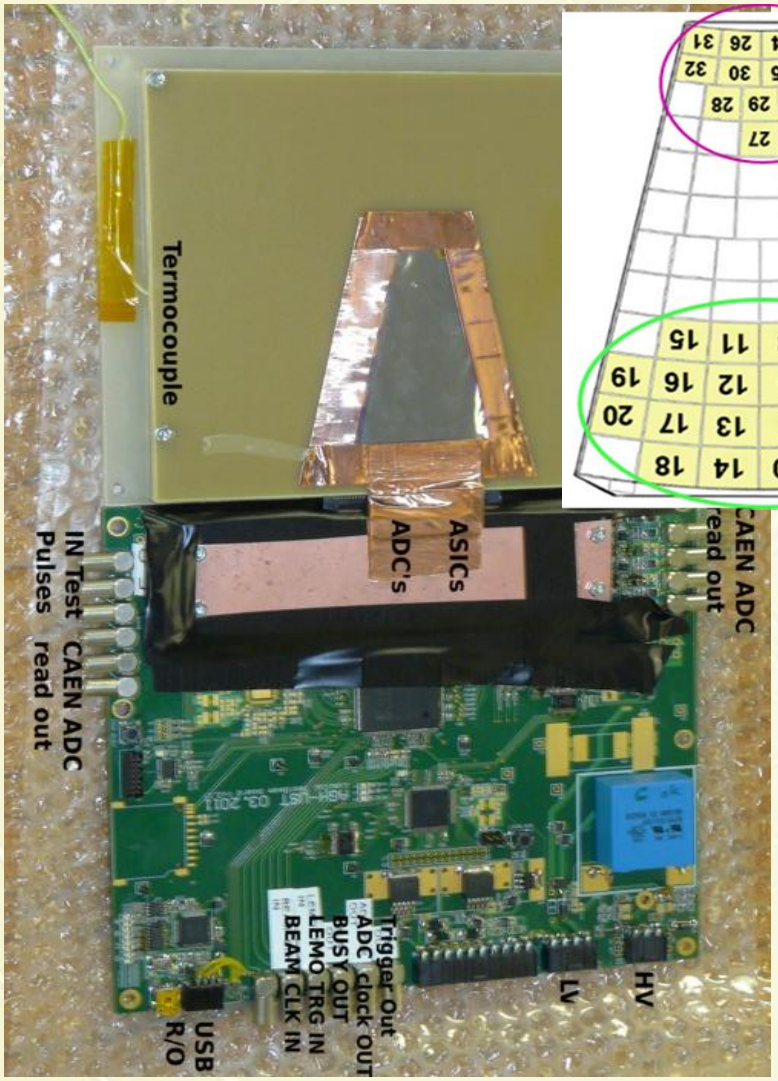


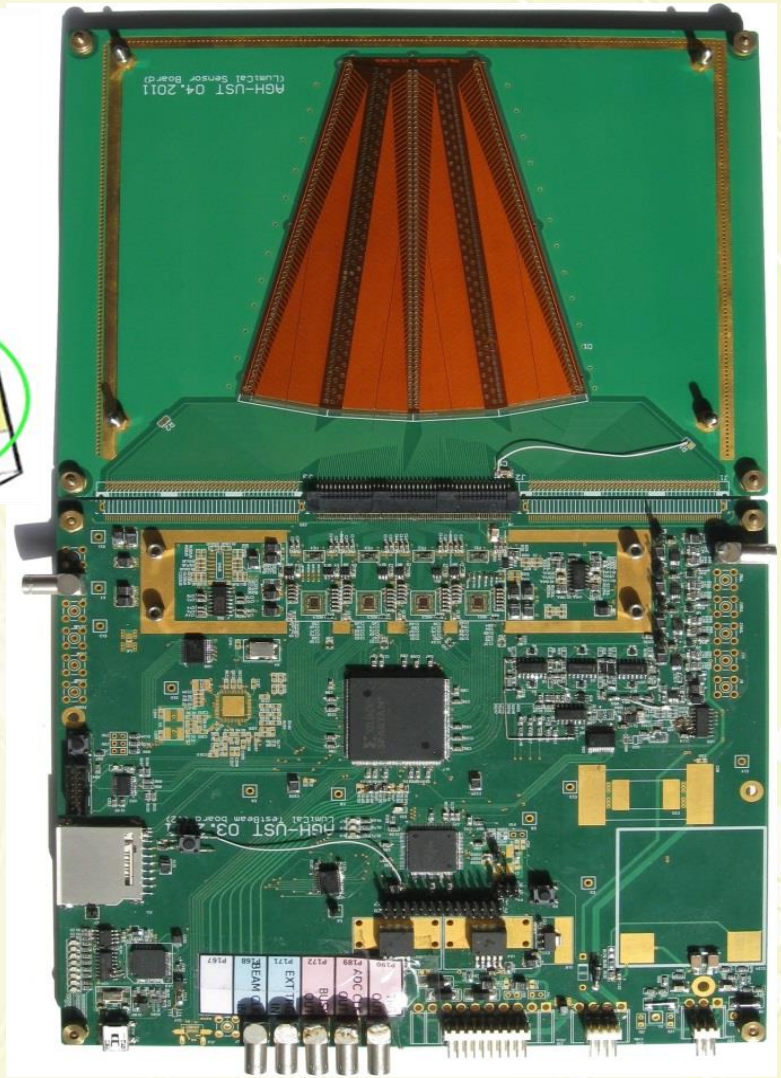
ÀDC ASIC, 8 channels, pipeline architecture, 10 bit

PCB instrumented with FE ASICs and 10 bit pipeline ADC ASICs for test-beam studies



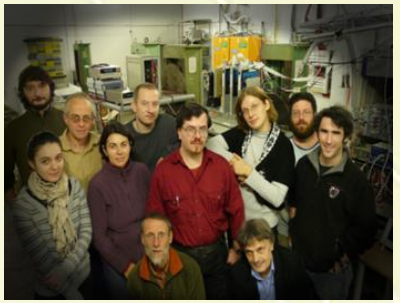
Fully Assembled Sensor Planes

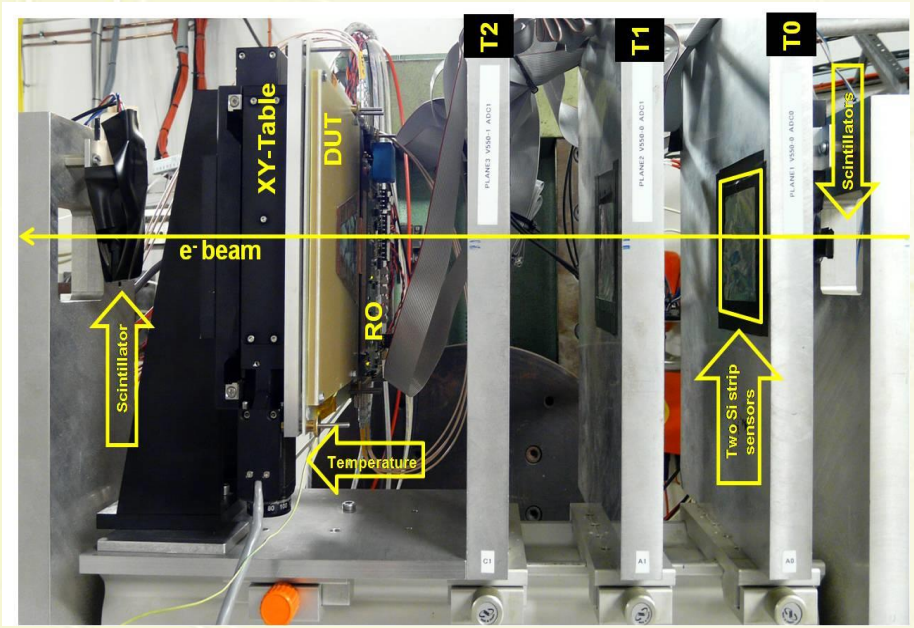


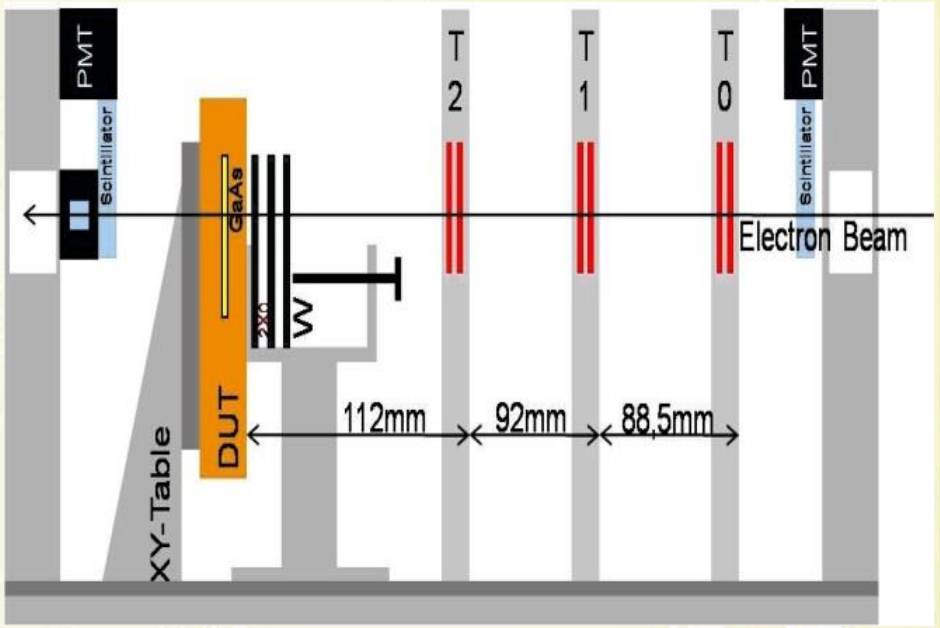


Testbeam Setup

electron beam 2-4.5 GeV at DESY
Silicon strip telescope, 10 μm spacepoint resolution
> 50 x 10^6 trigger







Beam Test Readout and DAQ

32 channels fully equipped
(Sensor + Front-end + ADC)

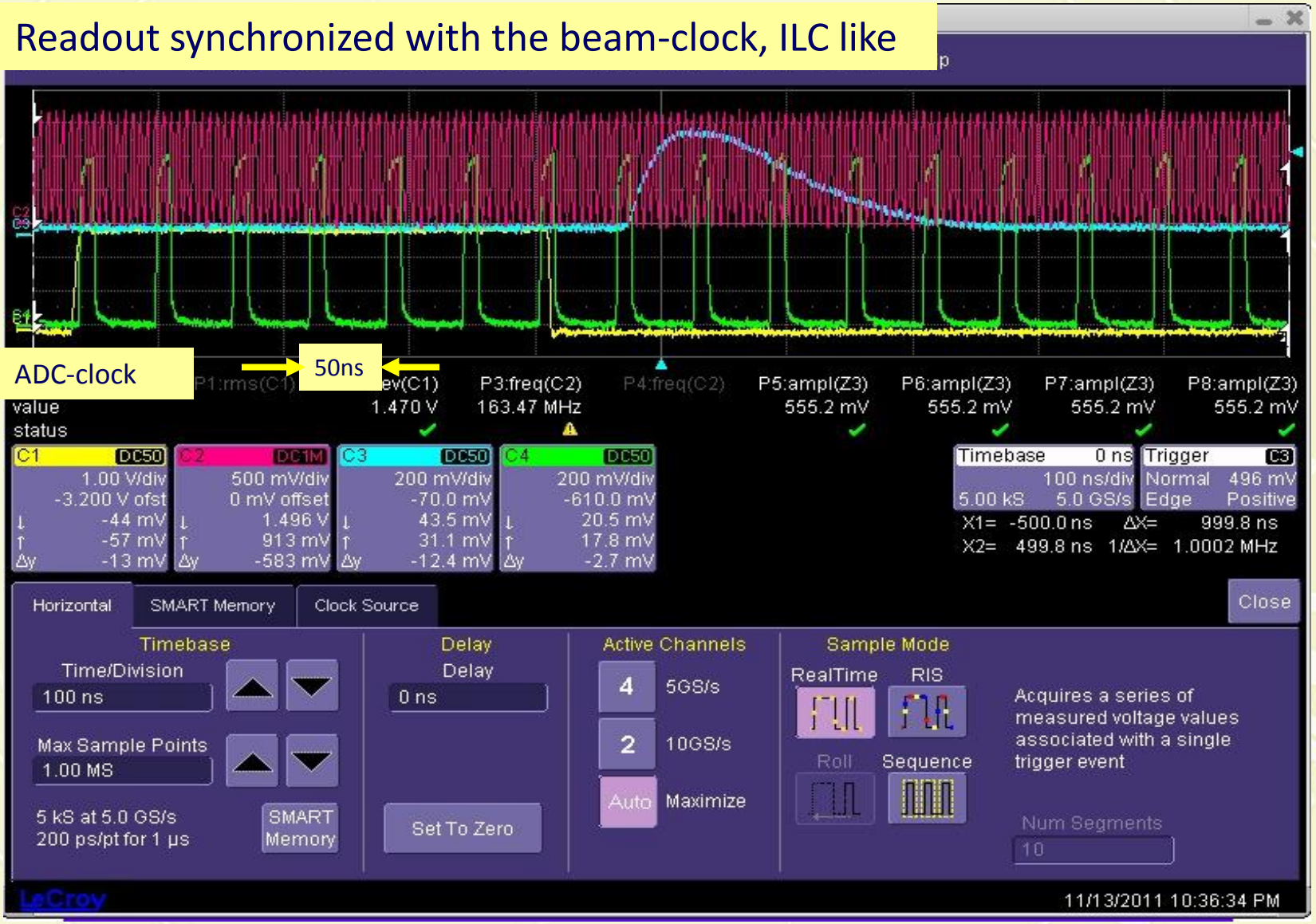
- Signal handshaking with Trigger Logic Unit (TLU)

  EUDAQ software

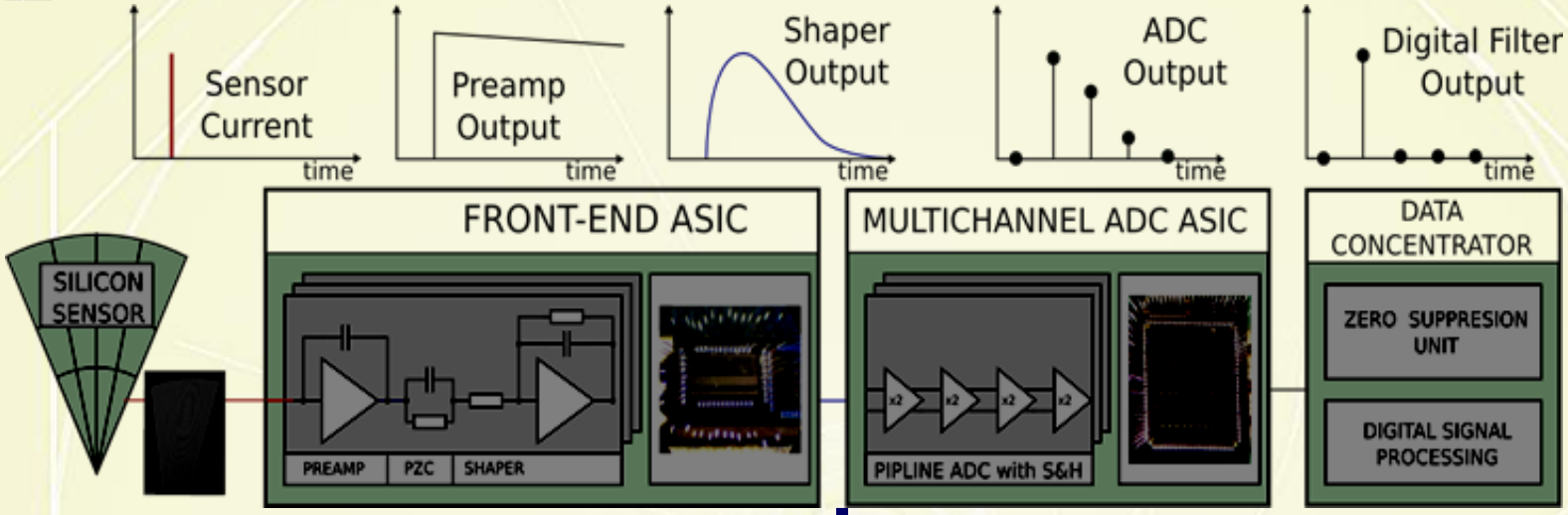
- ADC Clock source
  - Internal (asynchronous with beam operation) – CLIC mode
  - External (beam clock used to synchronize with beam) – ILC mode
  - ADC sampling rate is up to 20 Ms/s (6.4 Gbps)

Beam Test Readout and DAQ

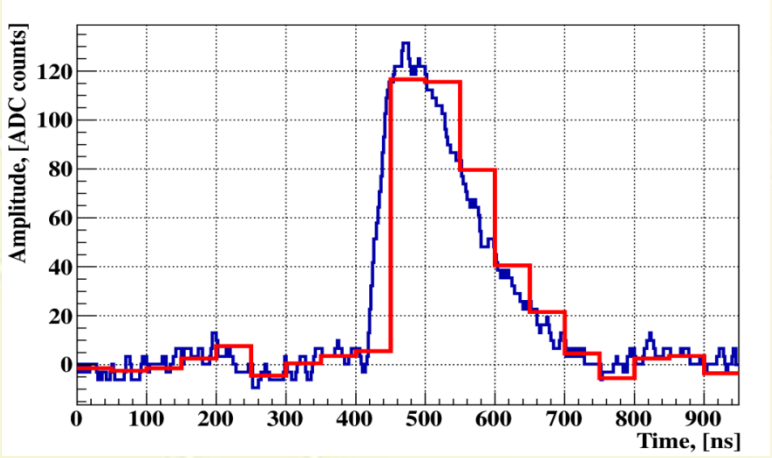
Readout synchronized with the beam-clock, ILC like



Readout Chain

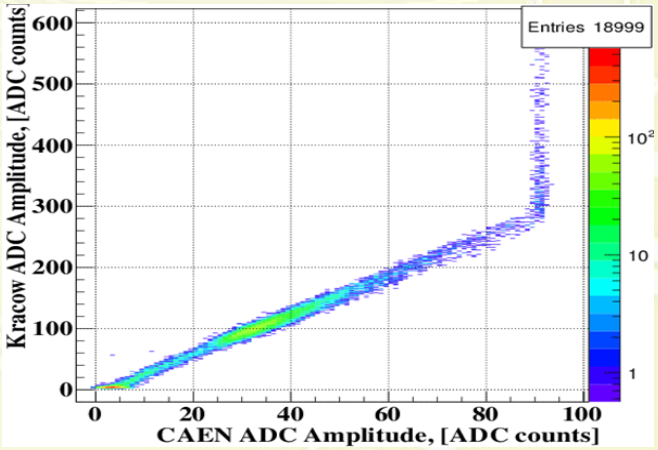


Example signal:
Signal digitized with ADC ASIC (red) and external ADC (blue)



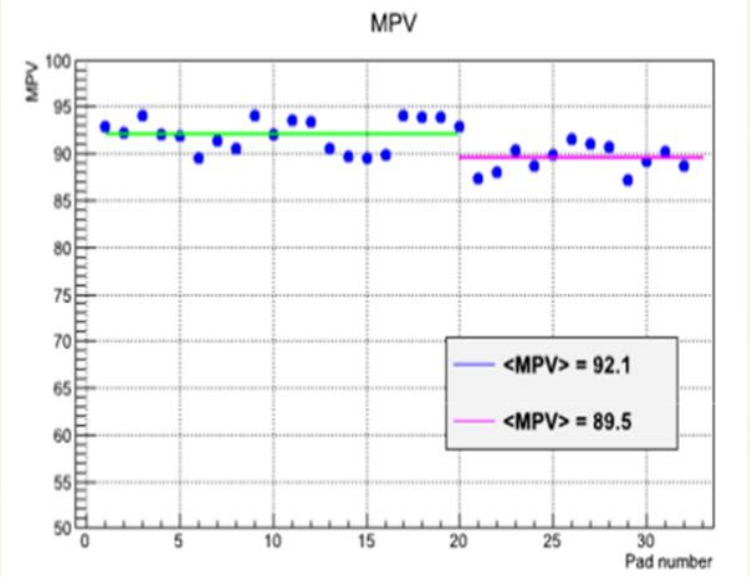
External 500 MS ADC

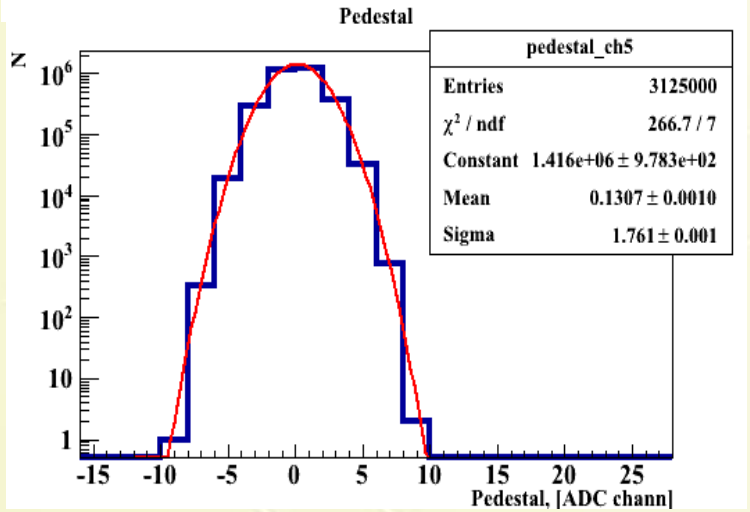
Comparison of the amplitude measured with the ADC ASIC and a CAEN 500 Ms/s flash ADC



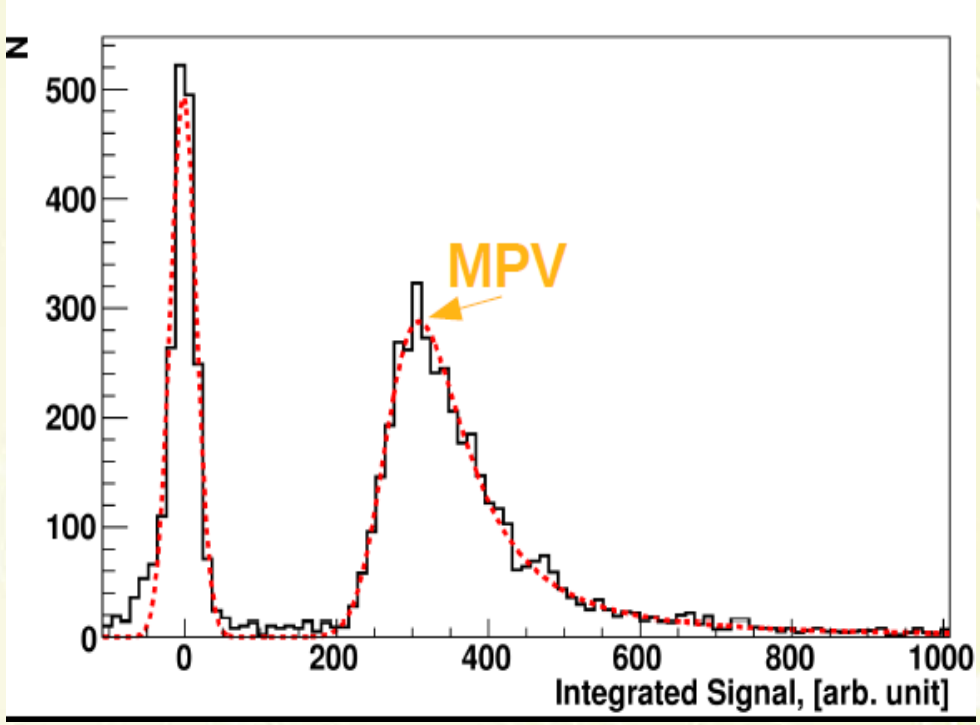
Beam-Test Results

Gain vs. channel



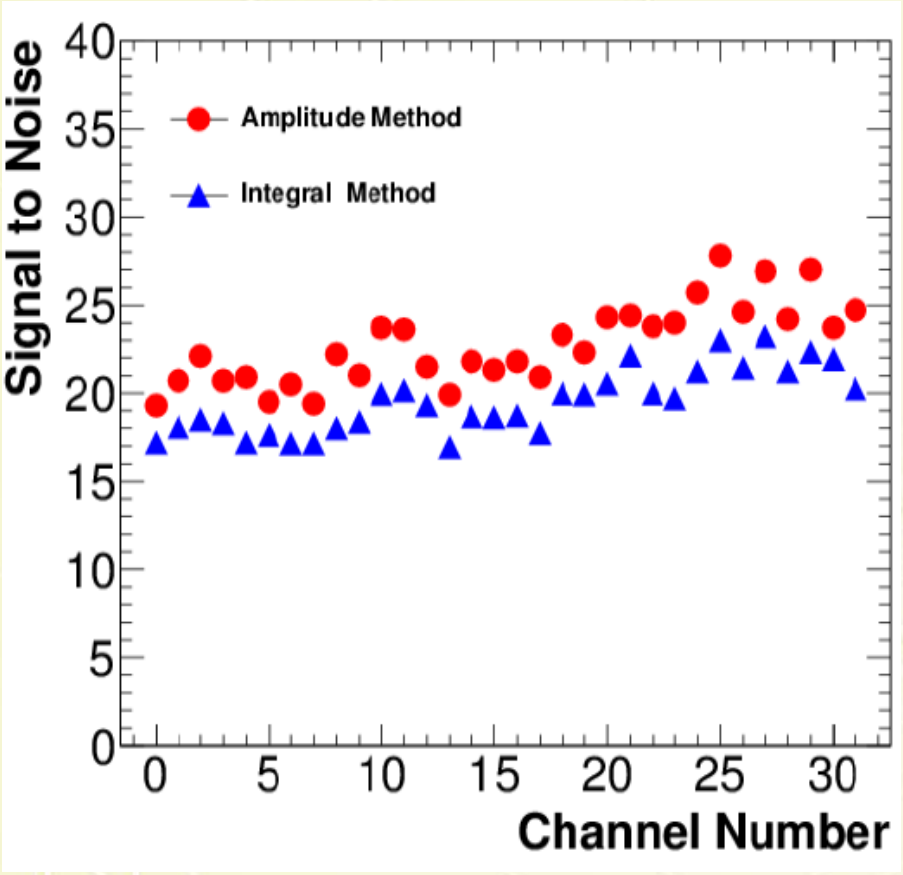


Triggered signal spectrum



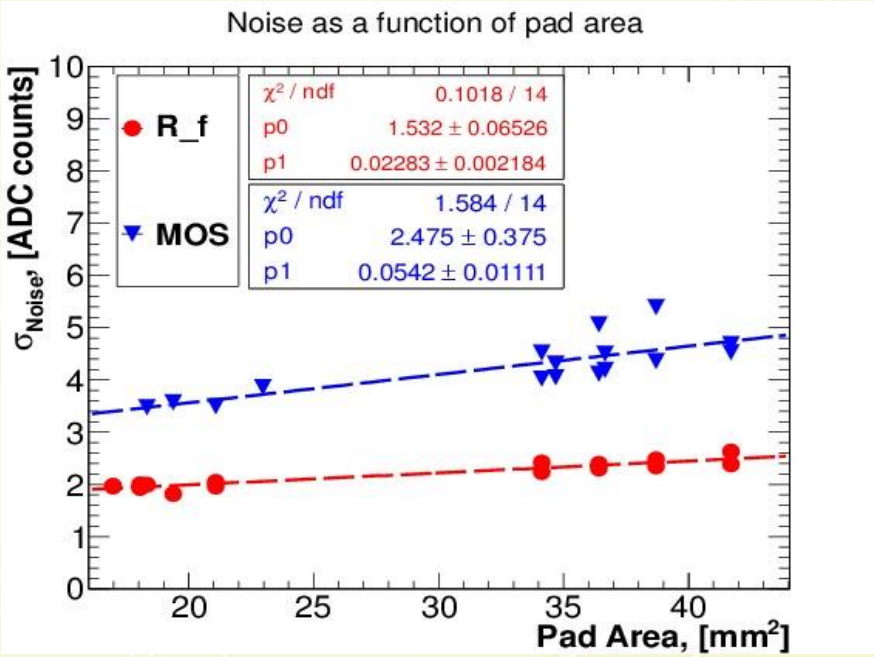
Pedestal
(taken from triggers without signal)

Beam-Test Results

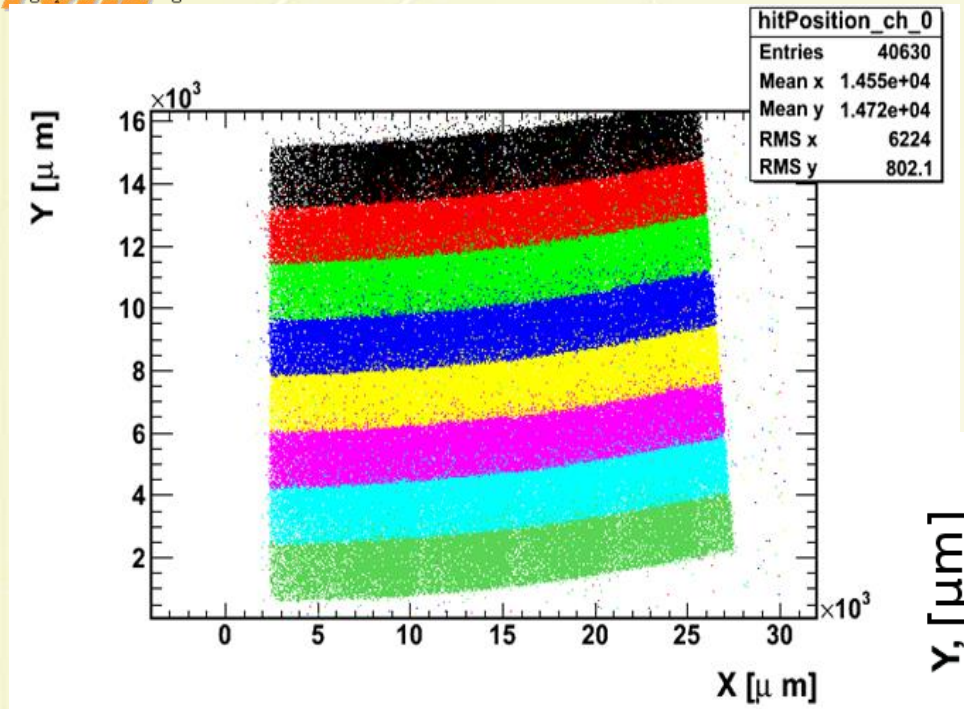


S/N from mips vs. channel
both for RC and FET feedback

Sigma(ped) as a function of the pad size

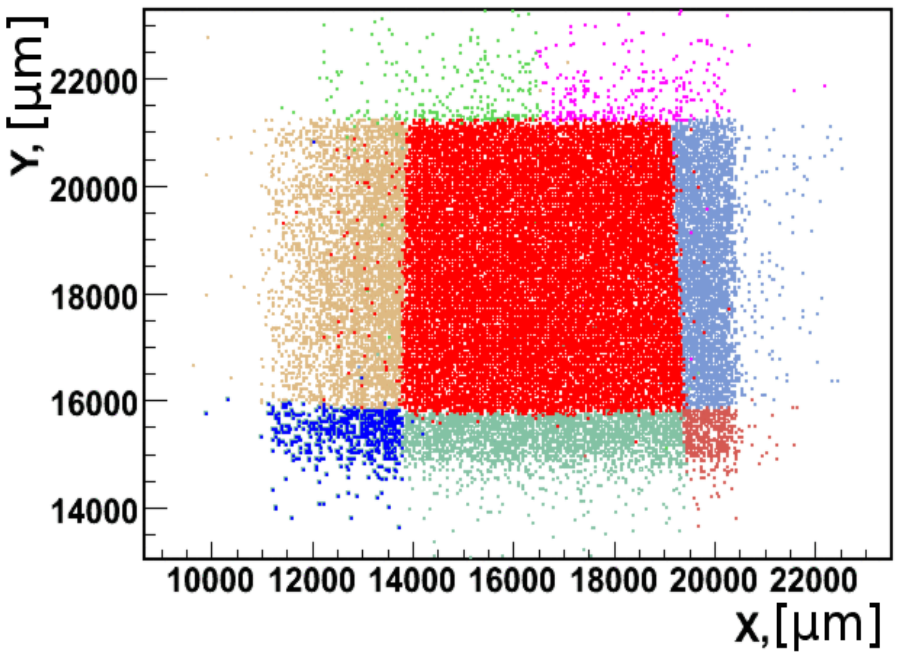


Beam-Test Results



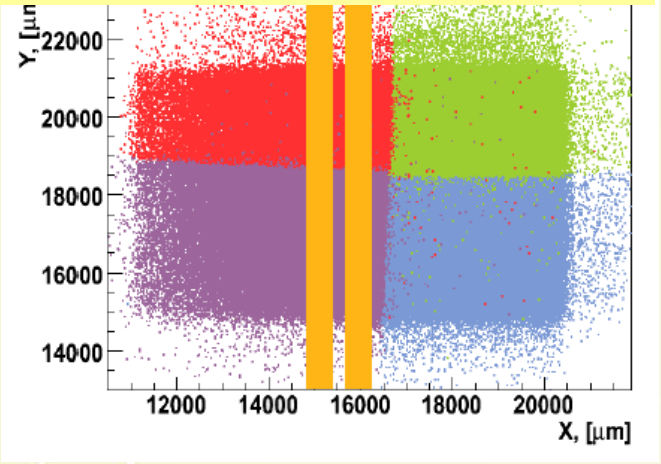
Impact point reconstruction using the beam telescope
LumiCal sensor

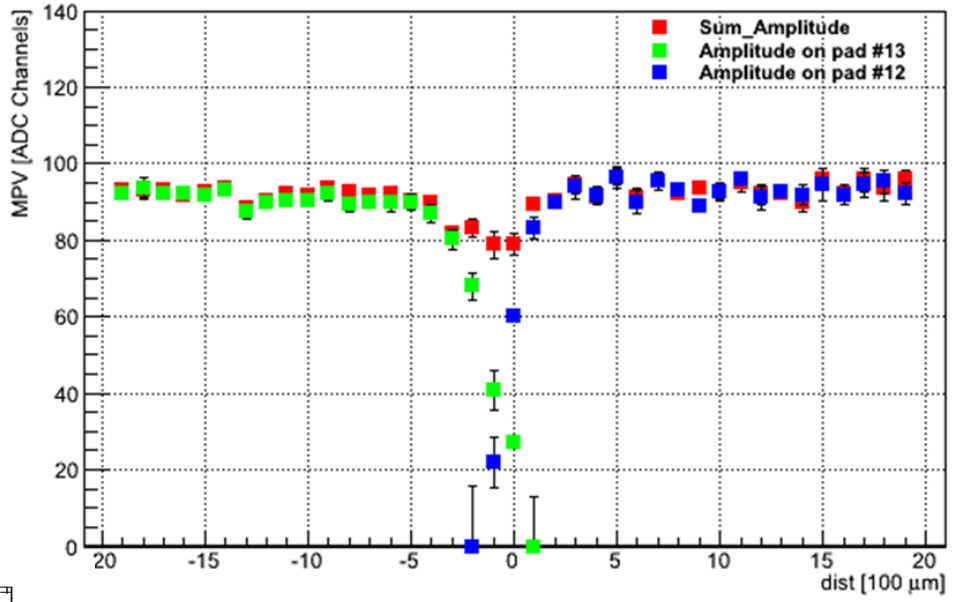
Impact point reconstruction using the beam telescope
BeamCal sensor

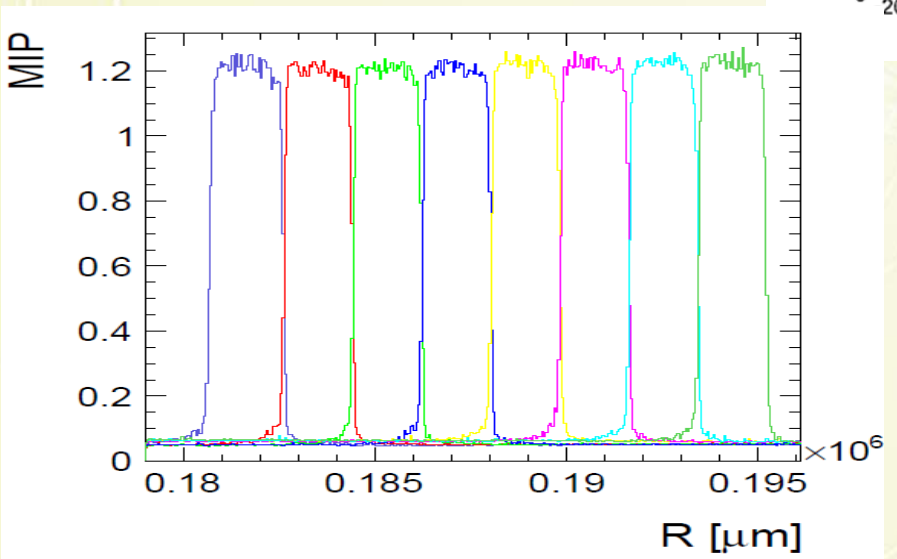


Beam-Test Results

Scan across a pad boundary





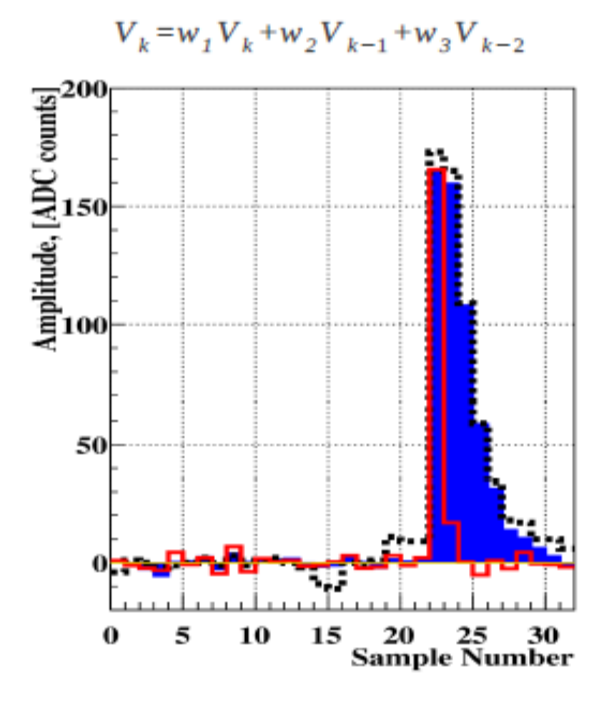


BeamCal sensor

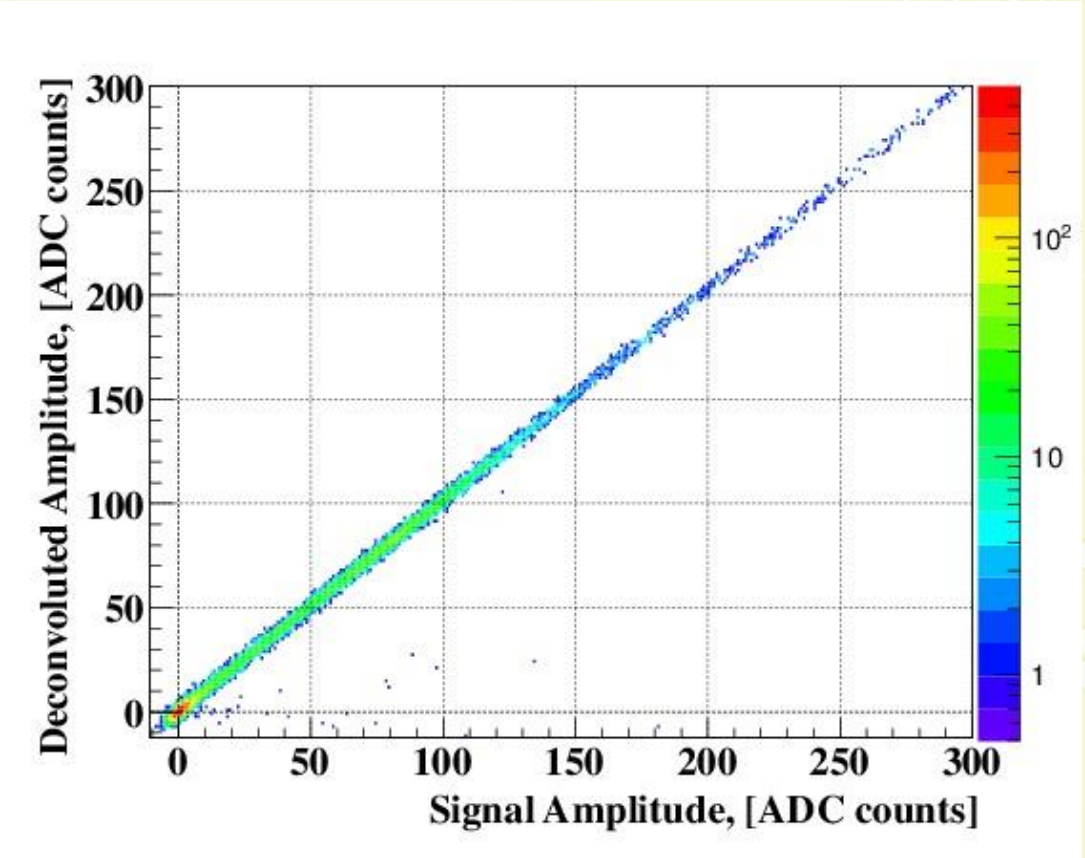
LumiCal sensor

Beam-Test Results

Data reduction and pile-up treatment by signal deconvolution

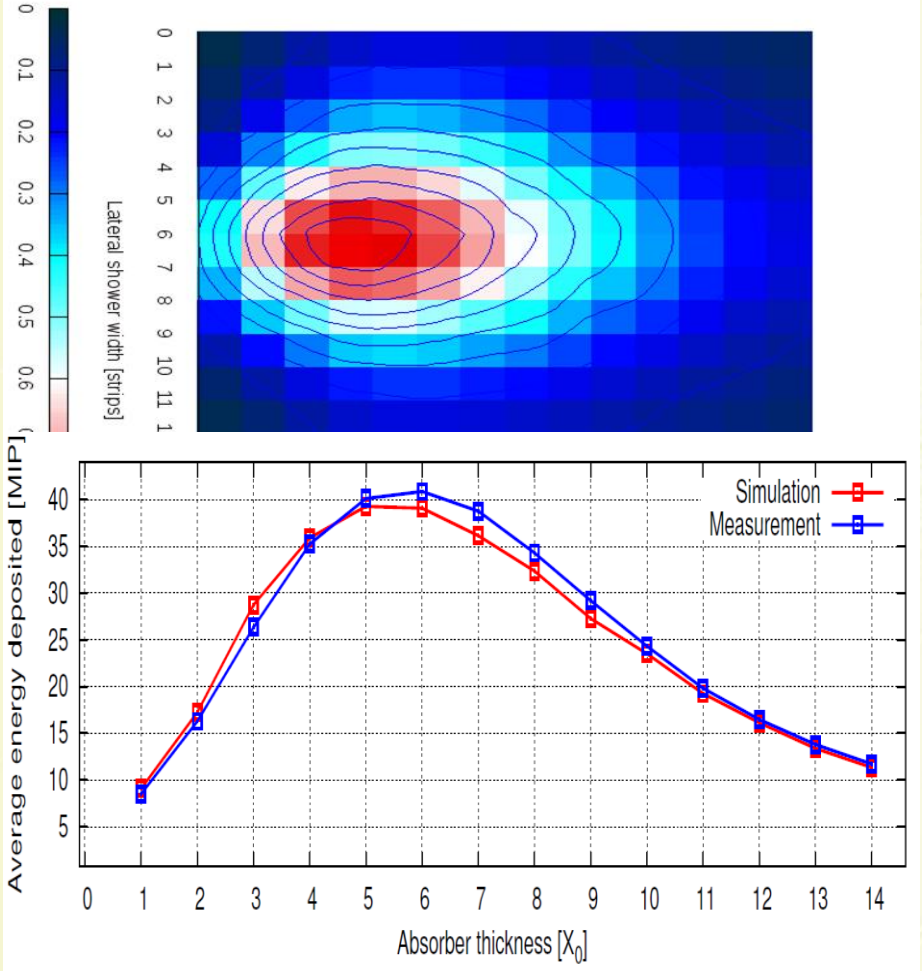


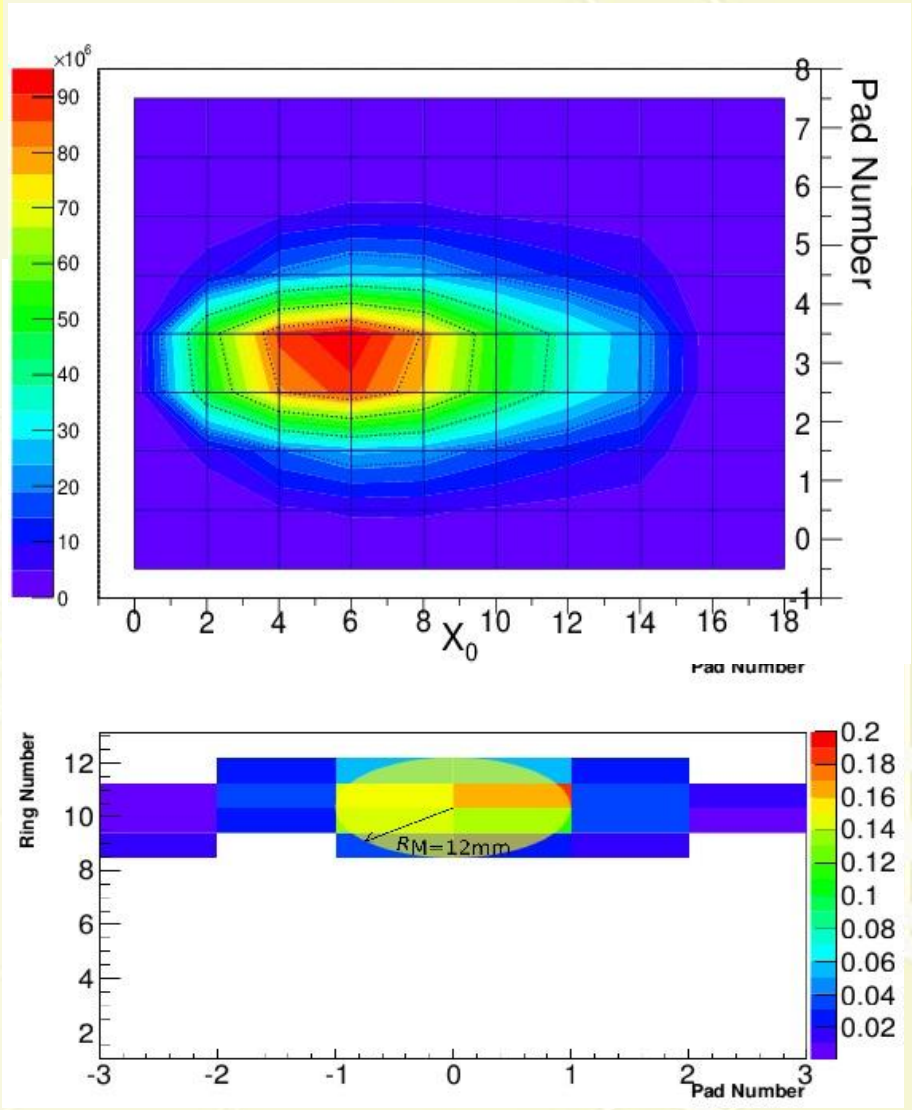
Reconstruction of the deconvoluted amplitude and comparison with full ADC information



Beam-Test Results

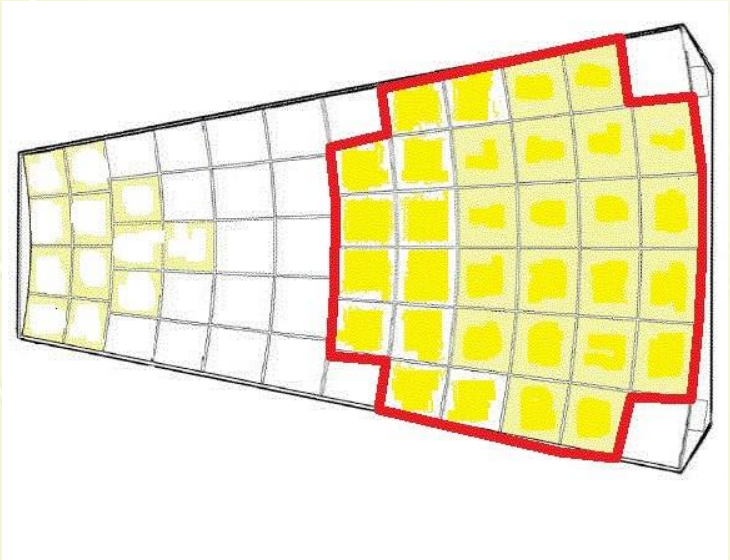
Shower profile measurements with n X_0 tungsten blocks in front of the sensors



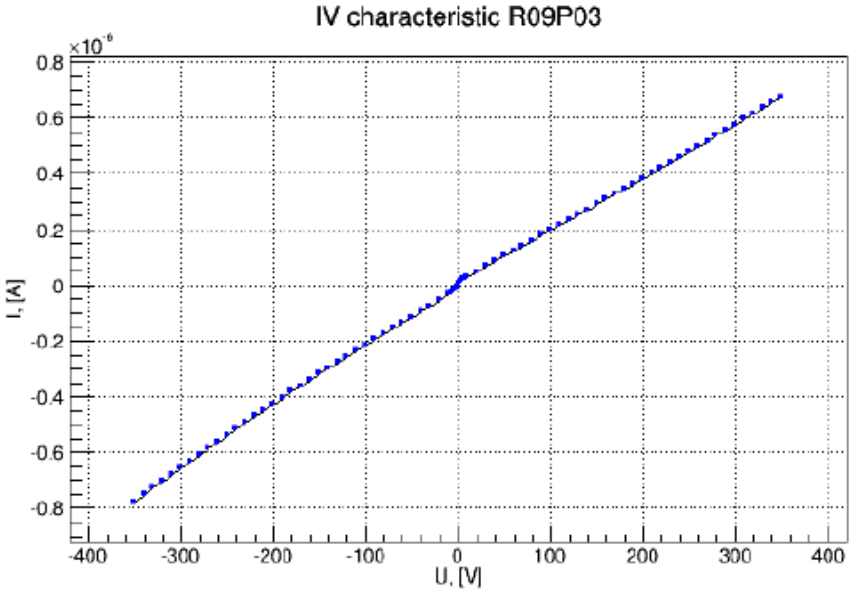


Current Preparations

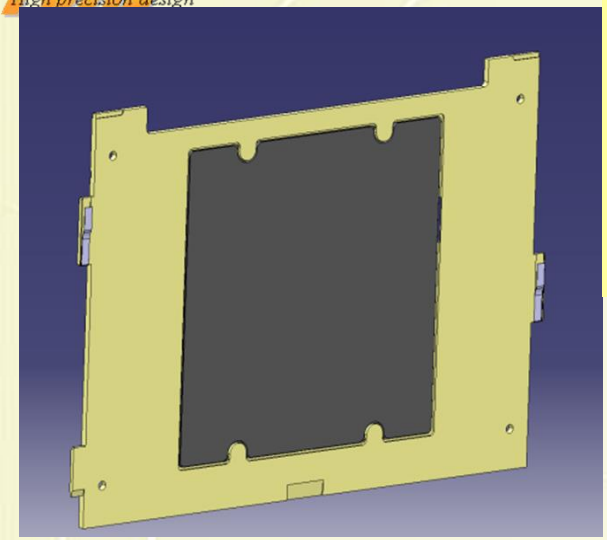
- Measurement of leakage current for each pad and guard ring
- Set criteria for later use in the prototype calorimeter



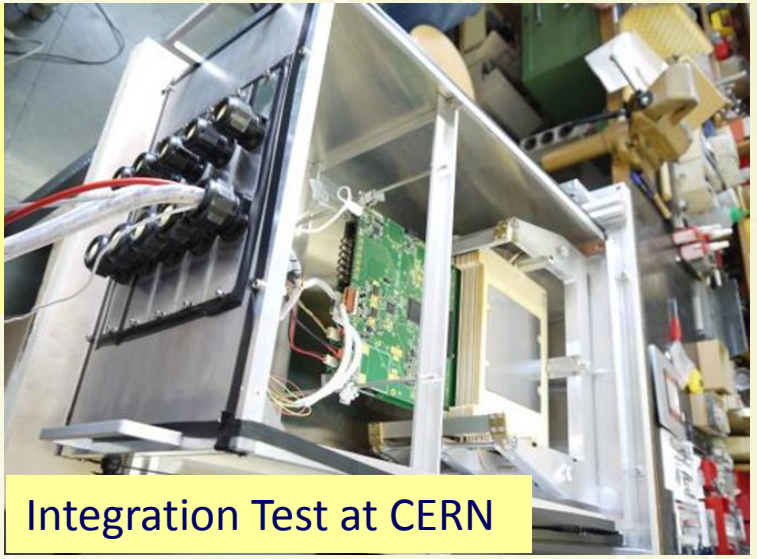
Typical IV of one pad (Ring 9 Pad 3) of AG262№20



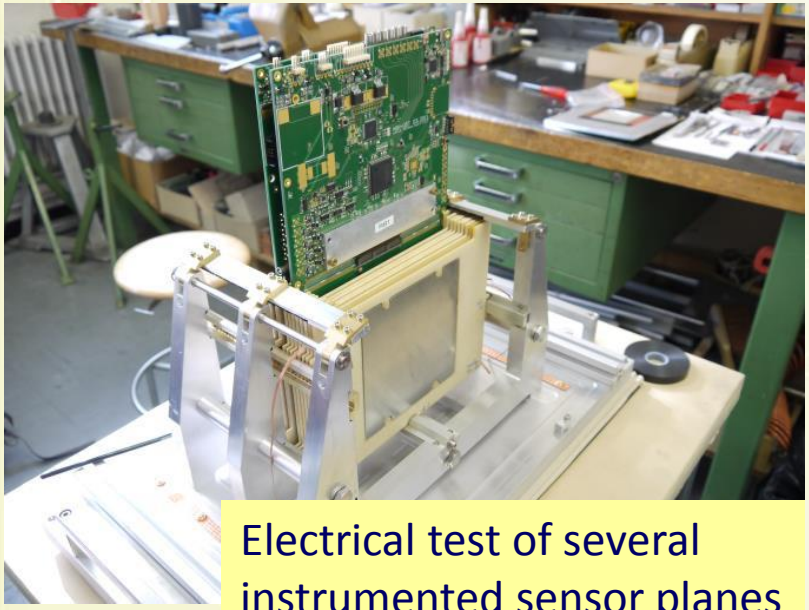
Beam-Test January 2014



Tungsten absorber plates (Plansee, MG Sanders , 11 pieces available)
Discussion with Russian vendors



Integration Test at CERN



Electrical test of several instrumented sensor planes

Testbeam Program:

- Operation of 4 instrumented planes
- DAQ extension
- Shower reconstruction and comparison with MC simulations

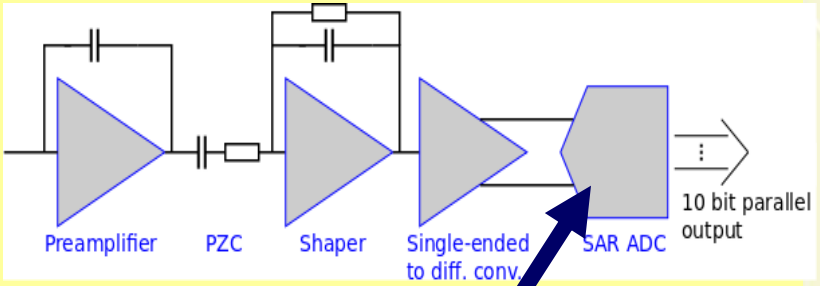
ASIC development, 130 nm

FE and ADC ASICs dedicated to LumiCal

130 nm IBM technology

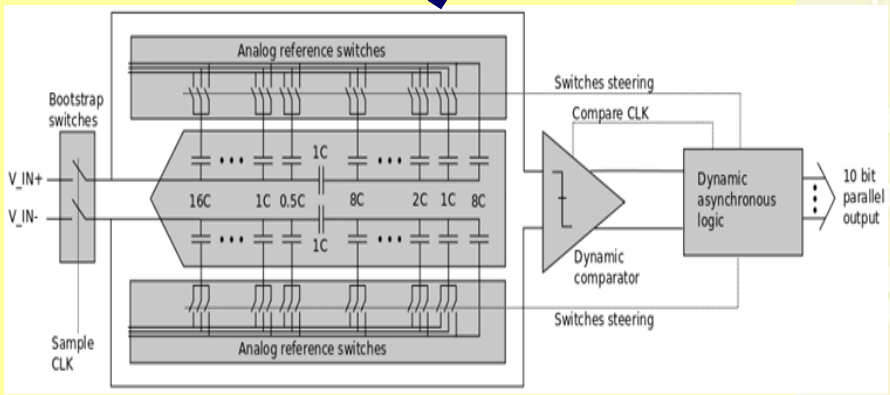
FE ASIC (submitted Feb. 2013)

- 8 channels per chip
- FE t_{peak} = 50 ns, dual gain
- 1.5 mW/channel, power pulsing



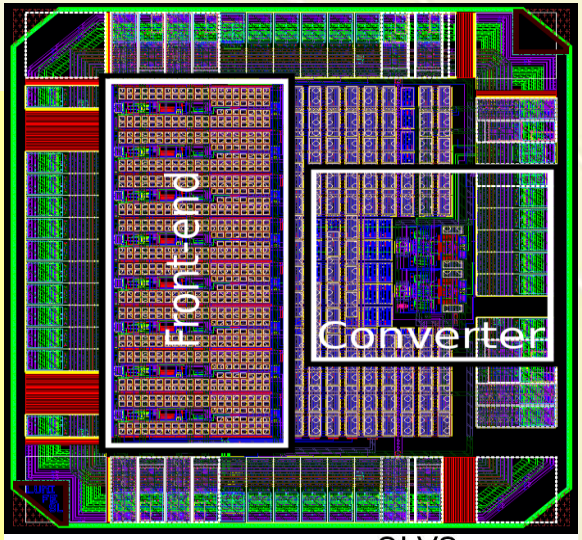
10 bit SAR ADC

- 8 channels per chip
- scalable frequency (up to 50 Ms/s)
- 1-2 mW at 40 MS/s, power pulsing
- PLL for data serialization
- high speed SLVS interface
- first prototypes 2012



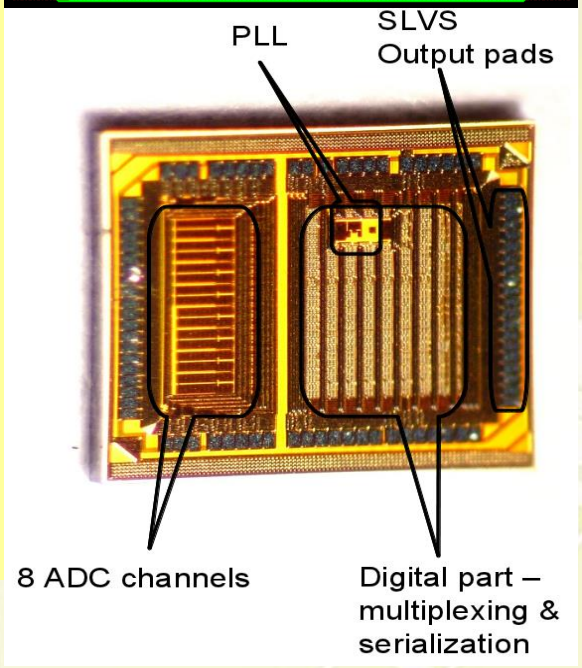
ASIC development, 130 nm

FE ASICs designed and submitted in February 2013, delivered in summer, tests started in October



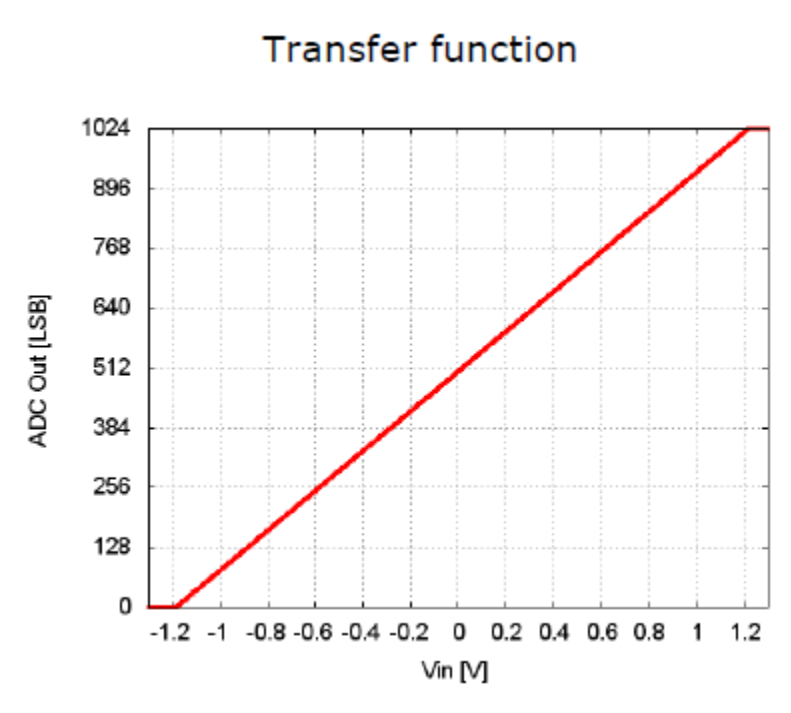
10 bit SAR ADC
Submitted and manufactured in 2012

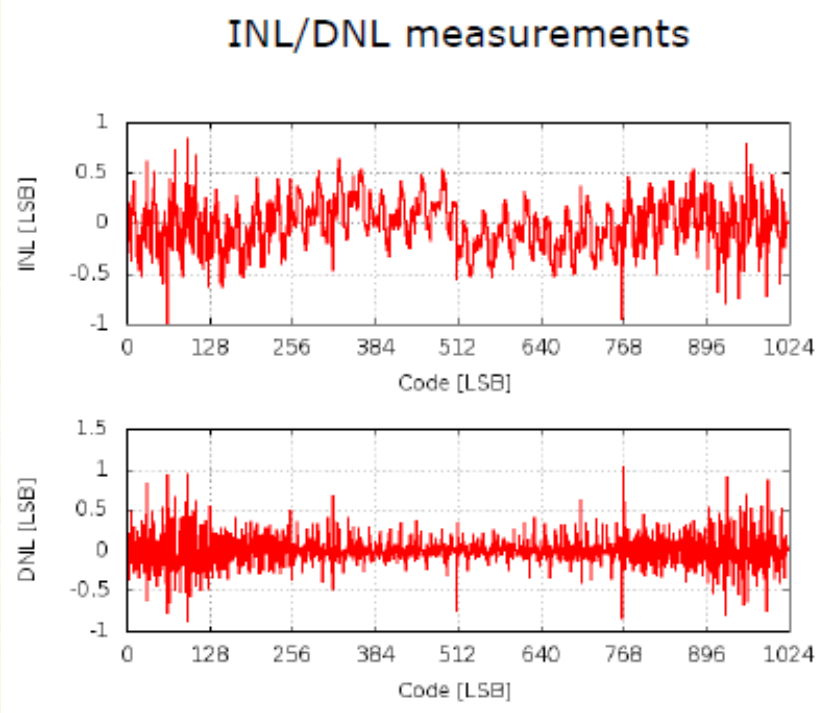
- fully functional
- ENOB 9.2
- at 40 MS/s 1 mW power
- power scaling 25 µW/channel/MHz
  (about a factor 40 less than the currently used ASICs in 350 nm technology)



ASIC development, 130 nm

Test results





- ADC almost linear over the full expected input signal range
- Some codes slightly worse, needs investigation
- Next submission: beginning 2014

ASIC development, 180 nm

FE and ADC ASICs dedicated to BeamCal and fast feedback

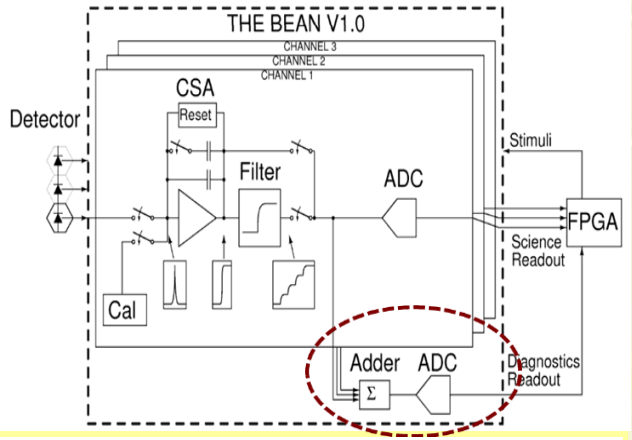
Bean, 180 nm TSMC technology

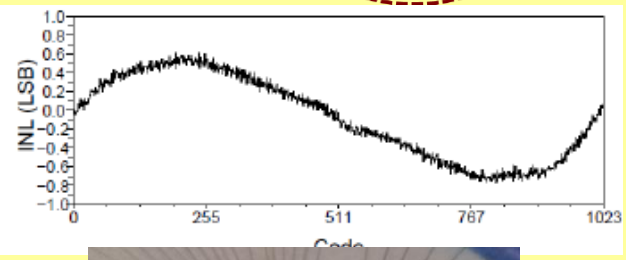
V1.0 (2010)

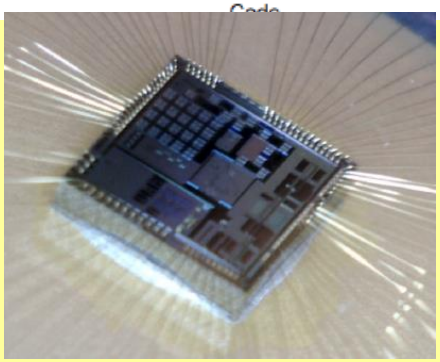
- 4 channels, SAR ADC
- 10 bit resolution
- 3.25 MS/s
- Systematic INL, reason found (layout and fabrication)
- test chip with configurable filters, promising results

V2.0 just under design

- 4 channels
- variable gain SCI
- Europractice, run in December
- New version Summer 2014 available







Summary

In Test-Beam Measurements 2010 and 2011 assembled sensor planes for BeamCal and LumiCal have been studied

- Sensors, FE and ADC ASICs matched the required performance
- Stable operation of the whole read out chain
- Very good S/N
- Some common noise
- Very good sensor homogeneity
- Small effect of inter-pad areas

For Future Beam-Tests

- Absorber structure for multi-layer measurements under test
- Next beam-test with 4 instrumented planes foreseen in January 2014
- Development of a new generation of ASICs well advanced
- Start of irradiation tests with silicon sensors (Talk given by Bruce)

Backups

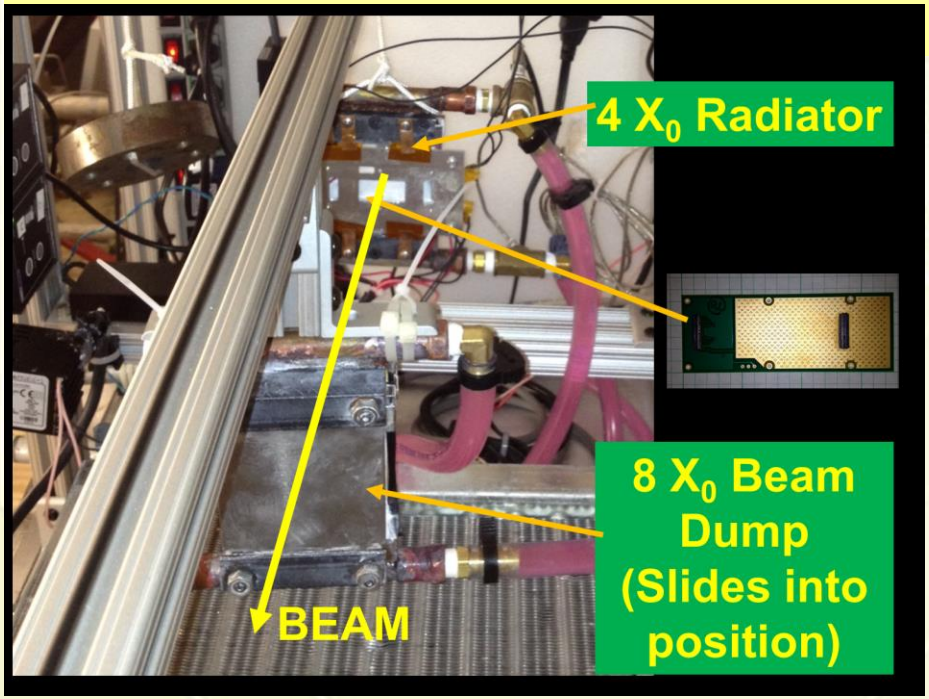
Sensor Irradiation Studies

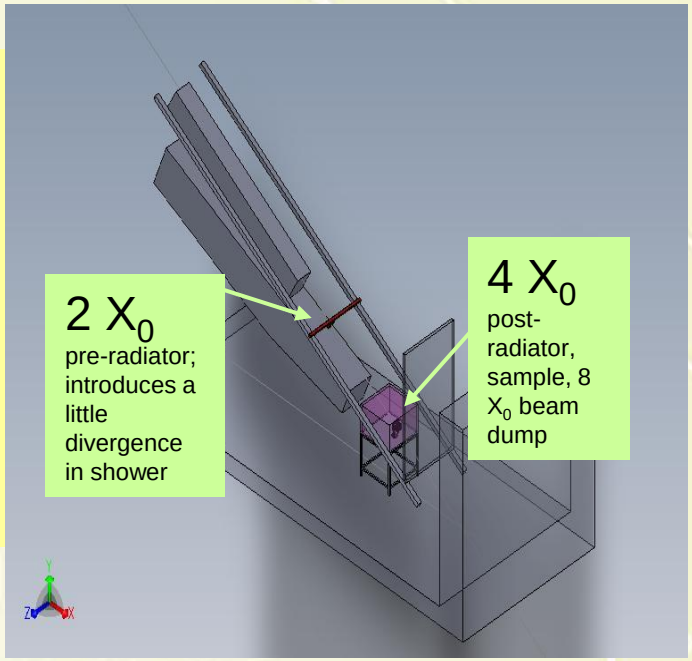
SLAC ESTB T- 506 beam

Study of radiation hard silicon sensors

- NIEL for electrons rel. small
- Hadrons in e.m. showers

Dose rate: 28 Mrad/hour

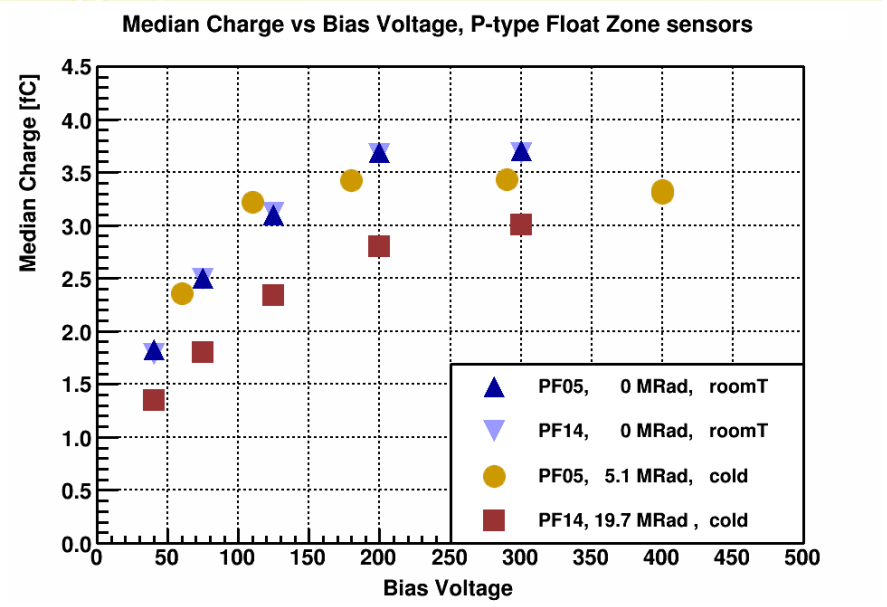


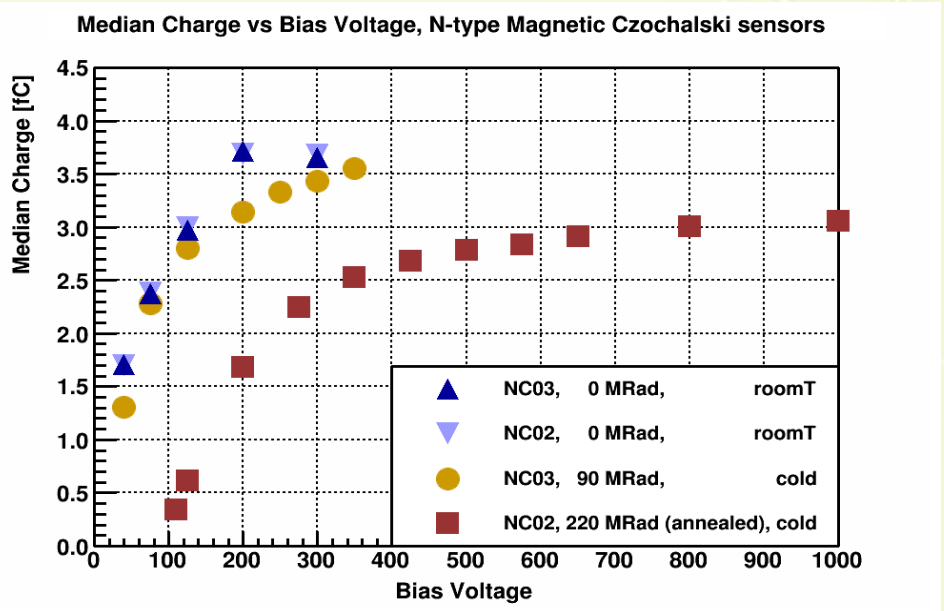


Sensor Irradiatiation Studies

Test of structures on different wafer

Results promising





To be done:

Confirm results at higher fluences

I/V and C/V measurements, annealin

Further runs with GaAs